

Unit IV More Applications of Kinematics and Dynamics

Things to Remember

Period: The time it takes to go through one revolution or cycle. Measured in seconds.

$$T = \frac{t}{\text{cycles}}$$

Frequency: How often something repeats itself; the number of cycles per second. Measured in Hz (/s).

$$f = \frac{\text{cycles}}{s}$$

Do remember that T and f are inverse of each other:

$$T = \frac{1}{f} \text{ and } f = \frac{1}{T}$$

Ex. A conventional, non-SSD hard drive of a computer is a metal disc that spins while data is written or read from it. The specs listed for a computer you are looking at is that the hard drive spins at 7200 rpm.

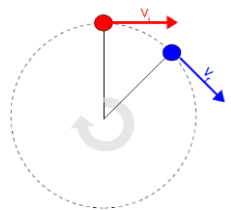
- a) What does this mean?
- b) Find its frequency and explain this measurement.
- c) Find its period.

Circular Motion

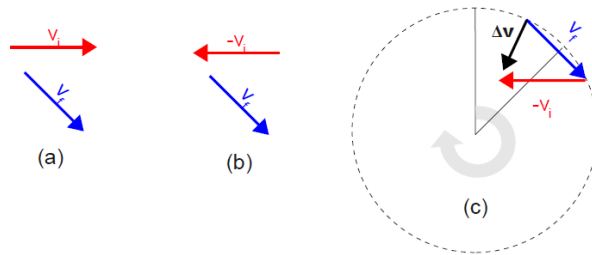
Think of spinning a yo-yo over your head. How would you describe its motion? Clearly, it moves in the path of a circle.

For all of our questions we do, assume that the object travelling in the circle is moving at a constant speed. Do not confuse speed with velocity, as the object is still accelerating due to a change in direction as it moves around the circle.

The velocity vector points along a tangent to the circle, in the direction that the object would tend to move if it were suddenly released.



The acceleration acts in the same direction as the change in velocity. The picture below shows the original vectors from the picture above (a) changed to show $-v_i$ (b) in order to find Δv (c). Notice the direction of Δv will always point towards the centre of the circle.



While travelling in the path of a circle, the acceleration is called centripetal acceleration. It always acts inward, toward the centre of the circle, in the same direction as the change in velocity, perpendicular to the velocity vector. Centripetal comes from Greek meaning “centre-seeking”.

Since we are moving at a constant speed, we can modify $\vec{v} = \frac{\Delta d}{\Delta t}$ to get:

$$\vec{v} = \frac{2\pi r}{t}$$

$\vec{v} = \frac{2\pi r}{t}$	Where v = velocity r = radius of circle t = time for one revolution
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Since t would be the time to go around one complete circle, you could substitute in period:

$\vec{v} = \frac{2\pi r}{T}$	Where v = velocity r = radius of circle T = Period
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Centripetal Acceleration

The magnitude of the centripetal acceleration is given by:

$\vec{a} = \frac{\vec{v}^2}{r}$	Where a = acceleration towards centre of circle r = radius of circle v = velocity of object
$\vec{a} = \frac{4\pi^2 r}{T^2}$	T = period of revolution
$\vec{a} = 4\pi^2 r f^2$	f = frequency of revolution

Ex. A DVD disc has a diameter of 12.0 cm and a rotational period of 0.100 s. Determine the centripetal acceleration at the outer edge of the disc

Centripetal Force

Since we have acceleration when going around a circle, we must also have an accompanying force. Using Newton's Second Law, we can derive a formula for this force that is in the same direction as the acceleration:

$\vec{F}_c = m\vec{a}_c$	Where F_c = centripetal force m = mass of object a_c = centripetal acceleration
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Furthermore, we can substitute any of our formulas for centripetal acceleration into Newton's Second law to get the following:

$\vec{F}_c = m \frac{\vec{v}^2}{r}$	$\vec{F}_c = \frac{4\pi^2 mr}{T^2}$	$\vec{F}_c = 4\pi^2 mrf^2$
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Ex. Determine the magnitude of the centripetal force exerted by the rim of a dragster's wheel on a 45.0-kg tire. The tire has a 0.480-m radius and is rotating at a speed of 30.0 m/s

Ex. Determine the maximum speed with which a 1500 kg car can safely travel around a circular track of 80.0 m if the coefficient of static friction between the tire and road is 0.30.

Universal Gravitation

Newton realized that the same gravity that keeps you on Earth also keeps the moon orbiting the Earth. This led to the idea of fields. A field is a region in space where one object can exert an influence on another object at a distance. A force is applied by one field acting on another similar field. The force of gravity involves the gravitational fields acting upon one another.

The field always points inwards towards the centre of mass. The gravitational force two objects experience are equal in magnitude but act in opposing directions. All masses have a gravitational field, but only the gravitational fields of large masses are noticeable.

Changes in altitude and longitude affect the gravitational field strength on the surface of the Earth. Changes in the composition of the Earth's crust also affect this strength.

The gravitational field strength is the force acting on a 1 kg mass.

Let's go back to Newton and his apple...

Newton started with the idea that since the Earth, is pulling on the apple, the apple must be pulling on the Earth (Newton 3). If the apple is pulling on the Earth, that means that the object does not have to be huge to be a source of gravity. There is nothing special about the Earth compared to the apple that creates gravity. This means that any mass pulls on any other mass.

Using lots of Calculus and some impressive physics, Newton came up with two key concepts:

- 1) The force due to gravity between two objects is proportional to the two masses.
- 2) The force due to gravity is inversely proportional to the square of the distance between the two masses.

The following formula was eventually arrived at:

$\vec{F}_g = \frac{Gm_1m_2}{d^2}$	Where F_g = force due to gravity (N) G = Universal Gravitational Constant = $6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$ m_1 = mass of object one (kg) m_2 = mass of object two (kg) d = distance between centres of the two objects (m)
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The Gravitational Constant, G , is a value that has been experimentally found. Physicists do not necessarily like formulas with constants, as it shows an incomplete understanding of a concept. Perhaps one day you will fix this embarrassing little problem for science.

Please note, G is not the same as g !

In practice, the weight of an object depends on its location with respect to one or more celestial bodies. Anything smaller doesn't exert much of a field.

Ex. You have a 200g pickles next to a 345 g sandwich on your plate. Their centres are 4.5 cm apart. Determine the force of gravity of the pickle pulling on the sandwich.

Ex. Io is one of Jupiter's moons. It is known to have 400 active volcanoes. One of the reasons for this is because of the gravitational pull of Jupiter on Io. At some time, the Sun, Io, and Jupiter are all lined up in a straight line so that both Sun and Jupiter were pulling Io in opposite directions. Using the data below, find the net force acting on Io at this time.

Celestial Body	Distance from Io (m)	Mass (kg)
Io	-	8.93×10^{22}
Jupiter	4.22×10^8	1.90×10^{27}
Sun	7.98×10^{11}	1.99×10^{30}